RAG

E
3 8.748
POS1901.7

REFERENCE

LIBRARY OF THE UNIVERSITY OF PENNSYLVANIA

E378.748

POS1901.7

GIFT OF

Univ.

(8)

Determination of
STEAM CONSUMPTION, COMMERCIAL EFFICIENCY AND LOSSES
of
WESTINGHOUSE STANDARD 25 H. P. ENGINE
and
DIRECT CONNECTED WESTINGHOUSE 16 K. W. GENERATOR

WALTER LOUIS FLEISHER

May 31, 1901.

---------o---------

E 378.748
POS 1901.7

✓

UNIVERSITY
of
PENNSYLVANIA
LIBRARIES

4 June 48. Sen. G. Luim. E.W.L.

The experiments and tests to be dealt with in this thesis were made on a Westinghouse engine (No. 4041) and a direct connected dynamo (50429), both mounted on a common bed-plate 3′ 2 1/2″ × 6′ 9 1/2″. This set has been in use about 10 hours a day for 4 years and has given good service with little expense for repairs.

The engine is the regulation Standard Westinghouse with two cylinders, single acting, cranks 180° apart. It has a stroke of 7″ and the diameter of the cylinder is 7 1/2″. The connecting rod is connected directly to the piston. The centre of the shaft is set 1 3/4″ over from centre of cylinders. The cranks and governors are encased and revolve in a mixture of oil and water.

The generator is a four-pole Westinghouse type, 15.6 K. W., 125 volts. The generator is connected to the engine shaft by a flexible spring coupling. The machine is over compounded and is rated to run at 375 R. P. M., but never goes that high, as only 110 volts are maintained at the terminals. The frame is cast around the cores of the field magnets. These cores are built up from wrought iron stampings, laminated to avoid eddy losses. The shunt and series windings are held in place by means of gun metal plates. There is a slotted drum armature, with four con-

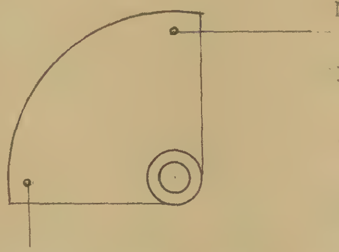
ductors in each slot. The coils are connected in parallel. There are four sets of carbon brushes, 2 brushes to a set, each set 90° from the other. The shunt coil is connected through a hand regulator to the positive terminal of the switch, and the potential is regulated by means of this.

The motion for the indicators was taken from the end of the shaft and, as the indicator cocks had to be put on the top of the cylinders, there was a considerable distance to run the cords that connected with the shaft and the indicator drums. The motion was transferred as follows:

A frame was constructed about the end of the shaft; on this frame were placed two iron guides in which slid cross-heads; from these cross-heads were attached links to a pin on a collar on the shaft. When the shaft revolved these cross-heads went up and down and to them could be attached cords from which the indicators could be moved. One guide was below and the other above the shaft. The pin to which the links were attached was 1 3/4" from the centre of the shaft; so the motion given to the indicator drums was 3 1/2", or one-half the length of the stroke. The guides were 9 1/4" long (see thesis of Messrs. Jones and Kerr, 1899, for diagram and detailed description: also thesis of Messrs. Kohn and Nusbaum, 1900, for photographs.

As I have mentioned before, the distance between the guides and the indicators was very great, considering the high speed at which the engine ran; the distance amounted to about 6 feet. In the past two years two other thesis of a like nature have been run on this engine, and in both of these there has been considerable trouble due to whipping of cords, stretching of cords and general instability and lack of firmness in the framing and connections. In fact, this whipping was so bad in one of the previous tests that the results obtained were quite worthless. Last year the gentlemen conducting the tests hit upon the idea of running the cords through straight lengths of glass tubing; the cords being taken over small pulleys to get from the horizontal to the vertical position of the strings. Since the pin from which the motion is derived is 1 3/4" from the centre of the shaft, the lengths of the cards should be very nearly 3.50". In the first thesis mentioned the cards varied from 3.86" to 4.20". With the glass tubing mentioned the cards varied from 3.61" to 3.78". A large part of the time spent by me was used in finding a way to reduce the length of the cards. The over-length had been attributed to many causes, namely: whipping, drum spring inefficiency and instability. The string used was claimed to be non-stretchable, so little at-

tention was paid to the fact that there might be stretching. By the aid of two superimposed lines, one taken at slow and the other at maximum speed, we found that the line lengthened on both sides. This showed conclusively that there was stretch in the string - other string was tried without success. Then a loss of about 1/32 of an inch was found in lost motion in the pulley at the turn, and a method for remedying this had to be considered. It was proposed taking two lengths of cord and fastening them to a large light sector thus:-



This was given up because the sector might have lost motion due to its bearing (*a*) not fitting. A glass rod, over which the cord might slip, was suggested; this brought up the idea of using a glass bend in which the cord could run. This was tried, the bend joining to the straight lengths.

We still had the stretch in the string to deal with. We discarded string altogether and used a fine brand of piano wire. The friction was so great between the glass and the wire that we almost gave up in despair, when the idea of lubricating with oil was thought of. This worked splendidly. There was only one trouble from now on. If there was a constant bending and straightening of the wire it was li-

able to snap in the course of an hour or two. Many thanks are due to Mr. A. William Schram for his suggestions and kind assistance in remedying these defects.

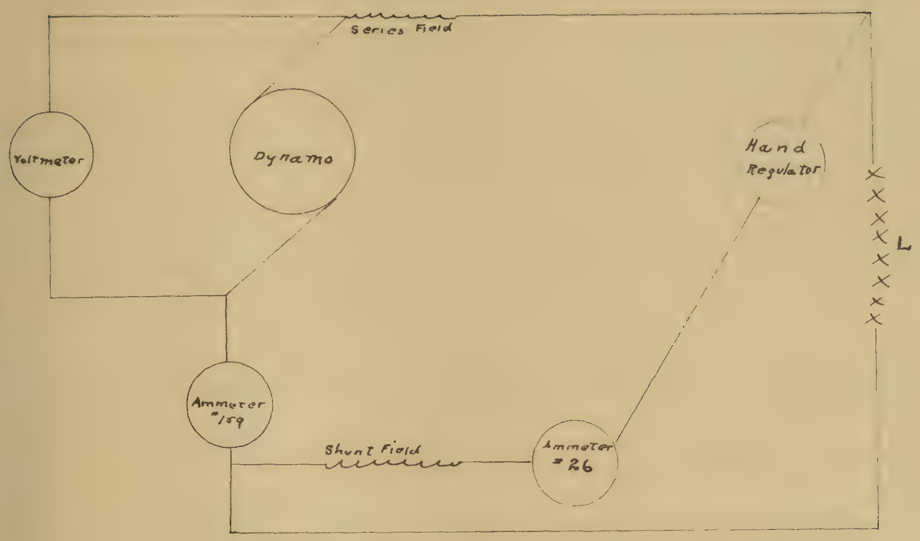
The indicators used were two Crosby High-speed Indicators (Nos. 7051, 7052) with a 50# spring in each.

Steam pressures were taken by a Crosby Steam Gauge (No. 189438) which was placed on a siphon attached to one of the parts of the sight-feed lubricator which is attached to the main steam pipe. The steam consumption was determined by running the exhaust steam through a surface condenser standing near the engine and to which there was a pass from the engine: this condenser was rated at 1000 lbs. per hour. This condenser when working at 500 lbs. and 600 lbs. of steam per hour worked very badly, so it would hardly be practicable to work it at its rated capacity.

It was necessary to determine the quality of the steam supplied to the engine in order to find what percentage of the condensed steam was chargeable to the engine. This quality was determined by means of a Barrus calorimeter placed on the supply steam pipe just above the throttle valve of the engine. In making the connection for this calorimeter quite some difficulty was found. There was a tee in the main pipe to which the calorimeter could be at-

tached; I threaded a piece of pipe for about 3″ of its length; in this length were drilled holes and the one end of the pipe was tapped and plugged; the other end was then threaded and a valve put on it. Now, by screwing this pipe well into the main pipe I obtained an effective steam drum that would insure a good quality of steam. The only trouble was it weakened, and leaked after being put in place. Five of these drums had to be made before a perfect one was obtained. To the other end of the valve was then attached the calorimeter, consisting of two thermometer wells and a plate through which the steam passed. The whole apparatus was well lagged with hair felt. The two thermometers used with this calorimeter were alternated in position, to eliminate errors due to the thermometers themselves.

The speed of the engine was obtained by means of a speed indicator held on the shaft. The electrical output of the machine was determined by placing an ammeter (#159) in the main circuit and a voltmeter (#24) across the terminals of the machine. An ammeter (#26) was also put in the shunt field to find the loss due to the C^2 R loss in the field:



The connections were made as shown above. L, the external load, was obtained by throwing on lights, motors, etc. in the different parts of the electrical service around the grounds, and varied considerably: therefore, a mean of all the values obtained in one test was taken. The electrical instruments were read as closely together as possible with the taking of the cards, but as no assistance was available often several minutes elapsed between reading the instruments and obtaining the cards.

The tests were of 1-hour duration each, with the exception of the full load test. which only lasted 40 minutes, due to the breaking of the wire in the indicator rig: still the results compared very favorably with general results

and no further tests were deemed necessary.

The water was weighed in a tank, on a Fairbanks' scale, readings being taken every ten minutes so that the values could be checked. Before the time to read the weight,- say one minute before,- the water was allowed to flow from the condenser into a bucket; then, at the exact instant that the ten-minutes interval had arrived, the water was allowed to flow into another bucket, while the water in the first bucket was poured into the tank and the weight of the water and tank taken. Then the water in the second bucket was put in the tank and weighed in with the next ten minutes' weight.

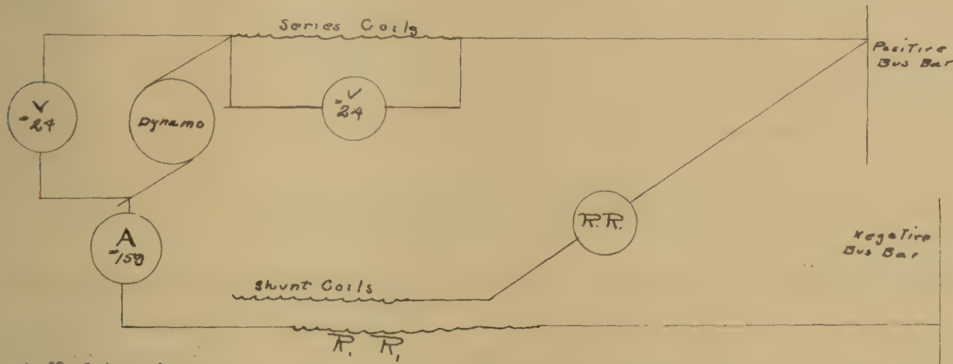
All instruments used were carefully calibrated. The gauge by which the upper temperature for the calorimeter was determined and which was also used to calibrate the indicator springs was itself calibrated by means of a Crosby gauge tester. A reading was taken on the gauge for every five pounds on the tester ascending and every five pounds descending from 0 to 110 pounds. The mean of the two readings was taken, and with this value as an abscissa and the test value as an ordinate a curve was drawn from which true values of pressure could be obtained. The springs were calibrated by placing the indicator on a manifold to which

steam could be admitted and controlled. To this manifold was also attached gauge #189438, steam was slowly admitted and, as the pressure rose as indicated on the gauge, lines were traced on a card that was on the drum of the indicator corresponding to the gauge pressure. Lines were drawn every 10 pounds for ascending values and every 10 pounds for descending values. Two cards for each value were taken, making eight cards in all. The ordinates were then measured and the true difference in pressure corresponding taken from the calibration curve of the gauge. Say ordinates = $\frac{g''}{100}$ and difference in pressure = p#, the 1″ ordinate = $\frac{y}{p}$. Thus we get the scale of the spring for several different places and take an average of them all.

The voltmeter was broken before it could be calibrated, so the values had to be assumed correct. The ammeters were calibrated by means of the hecto ampere balance of Lord Kelvin. Calibration of ammeter #159 was obtained from Messrs. Martindale and Williams, and of the low-reading voltmeters from Mr. S. B. Moore.

To get the resistance of the armature and series field a fall of potential method was used. In this experiment the voltmeter that I had intended using was broken and another low-reading voltmeter had to be used. This one

only read up to .7 of an volt, so a resistance was put in series with it to raise the reading. The original resistance was obtained by means of a whetstone bridge method and was found to be 70.85 ohms. I wished to read to about 2.5 volts, so a resistance of 212 ω was put in series with it. This brought the voltmeter readings high enough. Then the shunt field coils on the dynamo were disconnected; an ammeter (#159) and a resistance were put in series with the armature and series field and then the switch on the panel board was thrown onto the lower bars and a current taken from the other dynamos. Then the voltmeter was put across first the ammeter and carbon brushes together and then the series field and the potential noted. Then, knowing the current C and the fall of potential E, we get the resistance $=\frac{E}{C}$. The connections were as given below:-



V = Voltmeter
A = Ammeter
RR = Regulating resistance of shunt coil, disconnected
R.R.= " " for series

WORKING UP THE RESULTS

In working up the tests the mean of the several readings were taken, the mean of the first and last reading being taken as one reading. The total of the net water used divided by the number of hours the test was run gave the steam condensed per hour. The areas of the cards were found by means of a planimeter and the lengths were measured. Then for each side a mean area and a length was obtained as in the general readings; i,e., the mean of the first and last being counted as one value, and a mean ordinate obtained. Then the mean ordinate for the head and crank end were added together and multiplied by the scale of the spring. Then from the formula $\frac{P\ L\ A\ N}{3\ 3000}$ we got the horse-power.

P = sum of both ordinates × scale of springs;

L = length of stroke in feet;

A = area of piston in inches;

N = number of revolutions per minute.

To find the watts, we multiply the true volts × true amperes.

We get electrical horse-power by dividing by 746

$$E\ H\ P = \frac{V \times A}{746}$$

and the commercial efficiency = $\frac{E\ H\ P}{I\ H\ P}$

The steam condensed per I.H.P. hour and per kilo watt hour was then obtained by dividing the water actually used by the number of I.H.P or the number of kilo watts:

Kilo watt = 1000 watts

From the values obtained on the Farrus calorimeter we found the percentage of moisture in the steam as follows: We have often shown that when the steam enters the atmosphere superheated as shown by the lower thermometer, the quality of the steam is:

$$x_1 = \frac{q_2 + r_2 + .48(T\ \text{sup} - T\ \text{sat}) - q_1}{r_1}.$$

In this equation x_1 r_1 q_1 are obtained from a knowledge of the gauge pressure. The subscripts 2 are obtained from a knowledge of the barometer pressure and T sup is obtained from the temperature of the lower thermometer + the difference in temperature between that corresponding to the gauge and the upper thermometer. This is the loss due to radiation.

In the tests made by me there was such a discrepancy between the gauge and upper thermometer values that the radiation results were thrown out and a separate test was run with the calorimeter to find the radiation from the lower

thermometer. It was found to be 18.2° degrees (see page 50) this was therefore added to the mean of the lower thermometer readings of each test.

It has been shown very well (see A S.M E 1894) that the heat carried in by the entrained water performs no useful work and, therefore, should not enter into a calculation of the economy of the engine. Therefore, the total condensed water used was multiplied by x_1 to find the water usefully used. In working up the losses the mean current for a test was taken and squared; this was then multiplied by the resistance of the series field, then multiplied by the resistance of the armature. The resistance of the shunt coil, which was obtained by dividing the impressed E M F by the current in the field $\frac{E}{C}$ was equal to R, the resistance of the shunt field. This was then multiplied × C^2

$$\frac{E}{\cancel{C}} \times \cancel{C}^2 = E\,C.$$

These losses are all in watts.

In builders' specifications there is often a clause stating how much rise in temperature there will be with full load. It was shown last year that this was not excessive on this dynamo; therefore, no trial was made this year for temperature rise.

The losses in watts in the series, shunt and arma-

ture coils were added together and added to the output of the machine. The indicated horse-power was then multiplied × 746 to change it to watts; then the other values were subtracted and the result equaled the losses due to friction, eddy currents and hysterises.

A number of curves are shown, one being the calibration curve of the gauge abscissa = gauge readings ordinates true values. This is shown on page 35. A calibration curve of ammeter #26 is given on page 36. Amperes are given as abscissa and ordinates are true readings. A curve between I.H.P. and lbs. of water per I.H.P. per hour is given on page 37. A similar curve between kilo watts and lbs. of water per kilo watt per hour is given on page 38. Also a curve between K. W. output and losses, page 39. Then there is also a curve between commercial efficiency and kilo watts, page 40.

The results obtained from the tests carried out were much better than I ever could have hoped for. The water consumption decreased in proper ratios, the commercial efficiency is quite fair and the calorimeter results are passable. The cards were really excellent throughout. Friction, hysterises and eddy currents were not separately determined, as this would have entailed an excessive amount of work. The

results are most easily seen from the curves.

Walter Louis Fleisher

READINGS

U. of Pa. Test # 1 March 25 - 1901

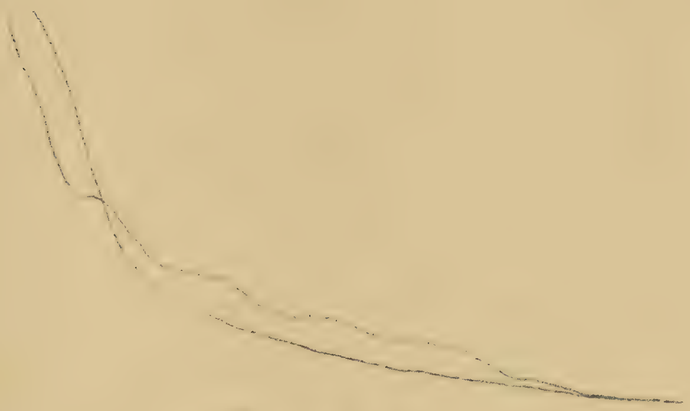
Time	T_1	T_2	P	Weight Tank Empty	Weight After 10 min	V	A_1	A_2	Rev per 2 min	Barom
4.40	282	234	102	164	228.5	0	0	0	183	29.823
4.50	280	250	98	228.5	285.5	0	0	0	183	
5.00	28	247	100	285.5	341.5	0	0	0	182	
5.10	282	247	101	341.5	396.5	0	0	0	177	
5.20	28	250	100	396.5	450	0	0	0	178	
5.30	282	248	104	450	508	0	0	0	181	
5.40	280	250	100			0	0	0	186	
Sum	not used	484	605		344				1090	
Mean		247.3	100.83			0	0	0	180.9	29.823

Test #, Cont.

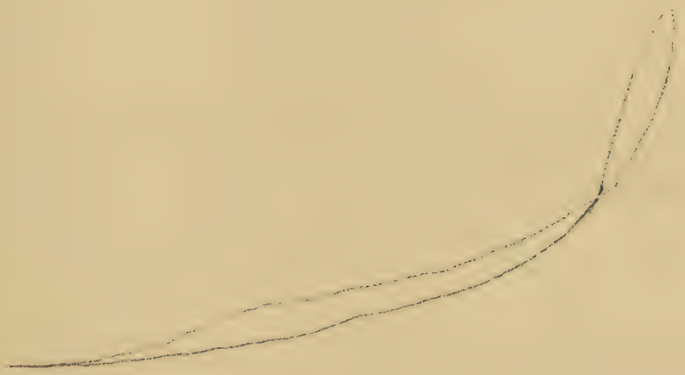
Time	Cards		Length		Area	
	L	R	L	R	L	R
4 46	1	1	3 5	3.53	.10	55
4 56	2	2	3 5	3.53	.5	.25
5 06	3	3	3.52	3.54	.8	.7
5 16	4	4	3.53	3 56	20	10
5 26	5	5	3 53	3.57	.9	85
5 30	-	6	-	3.4		.3
Sum			.760	91	.77	.783
Mean			352	802	354	566

Test #1

Sample Cards



Right



LEFT

~ of P_1 Test #2. April 1st 1901

Time	—	T_2	P	Weight Tank Empty	Weight After 10 min	Volts	A_F	A_c	Rev per 1/2 m	Bar.
220	275	233	95	179	226.75	109.5	4.0	68	183	30.134
2.30	279	243	101	226.75	324.5	109.25	4.0	6	181	
2.40	279	245	105	324.5	415	108.5	3.96	55.25	192	
2.50	278	252	100	415	553.5	108	4.00	53	188	
3.00	272	240	98	553.5	642.5	107	3.90	53	188	
310	282	248	100	195.5	286	108	3.96	58.5	181	
320	286	250	104	286	–	108.5	3.97	56.75	187	
Sum	Not Used	1469.5	602.5		554	649.5	23.865	338.12	1120.8	
Mean		244.9	100.41			108.25	3.967	56.25	186.8	

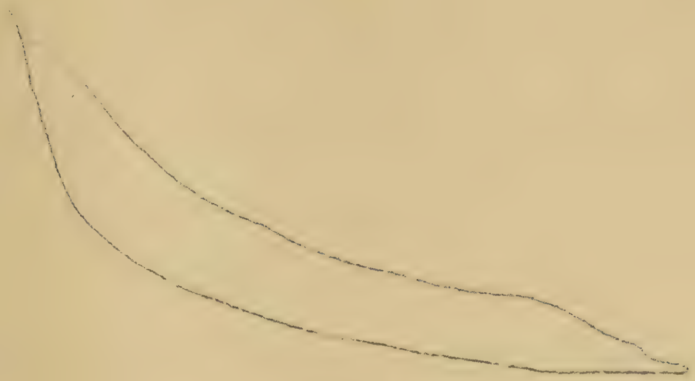
Test #2 cont.

Time	Cards		Length		Area	
	L	R	L	R	L	R
2.20	1	1	3.52	354	1.28	1.46
2.30	2	2	353	354	1.20	1.39
2.40	3	3	3.52	354	1.15	1.35
2.50	4	4	3.55	354	1.21	1.33
300	5	5	353	354	1.14	1.34
3.10	6	6	352	353	1.15	1.38
3.20	-	7	-	354	-	1.47
Sum			2117	2477	7.13	8.215
Mean			3.528	3.54	118.88	136.91

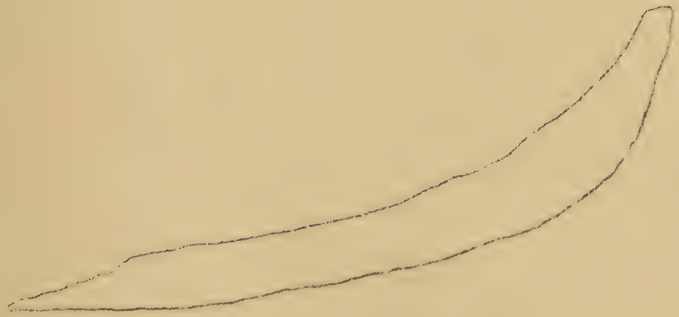
UNIVERSITY
OF
PENNSYLVANIA
LIBRARIES

Test #2

Sample Cards



Right



Left

U. of PA. Test #3 April 1st 1901

Time	T_1	T_2	P	Weight Tank Empty	Weight after 10 min	Volts	A_F	A_c	Rev per 1/2 min	Barom
4.15	282	240	.05	745	264	.09	3.95	54	.82	30.134
4.25	280	251	.00	264	357.5	110	4.17	59.5	183	
4.35	279	250	.10	357.5	441	115	4.14	48	183	
4.45	250	250	02	441	530	111	4.12	48.25	189	
4.55	282	250	104	234	322	110.5	4.12	50	187	
5.05	280	251	03	322	414.5	109.5	4.00	50	180	
5.15	279	250	.00	414.5		07.25	3.97	53	.88	
Sum	NOT USED	1500	612.5		536	664.13	24.51	309.25	1113	
Mean		250	102.08			110.69	4.085	51.54	1855	

Test # 3 cont.

Time	Cards		Length		Area	
	L	R	L	R	L	R
4.15	1		353	353	1.18	1.39
4.25	2	2	354	353	1.24	1.63
4.35	3	3	354	354	1.02	1.20
4.45	4	4	355	355	1.02	1.27
4.55	5	5	354	353	1.12	1.30
5.05	6	6	354	354	1.16	1.38
5.15	7	7	354	354	1.19	1.40
Sum			2124.6	2122.5	6.745	8.175
Mean			354.1	353.75	1.124	1.3625

Test #5

Sample Card

Right

Left

U. of Pa Test #4 April 15TH 1901

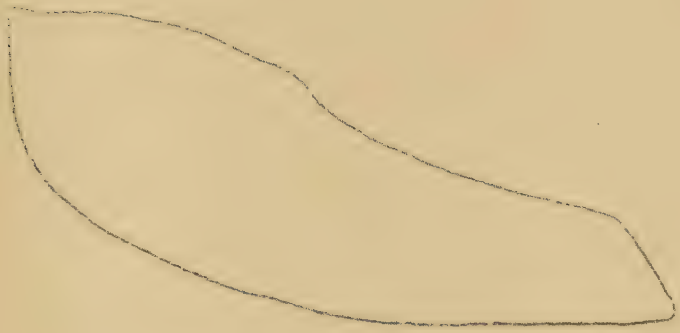
Time	T_1	T_2	P	Weight Tank Empty	Weight after 10 min.	Volts	A_F	A_c	Rev per min	Barom
.22	286	246	96	210	354.5	111.5	4.05	111	181	29.812
.32	287	257	98	354.5	482	112	4 [illegible]	99	182	
1.42	284	257	96	482	612.5	111.5	4.15	.05	181	
1.52	282	257	92	350	491	111.5	4.20	.04	182	
2.02	283	257	93	274.5	416	113.5	4.20	1.05	184	
Sum	Not	1022.5	380.5		543.5	447.5	[illegible]	418.75	727.40	
Mean	used	255.6	95.13			111.875	[illegible]	104.69	181.85	

Test #4 cont

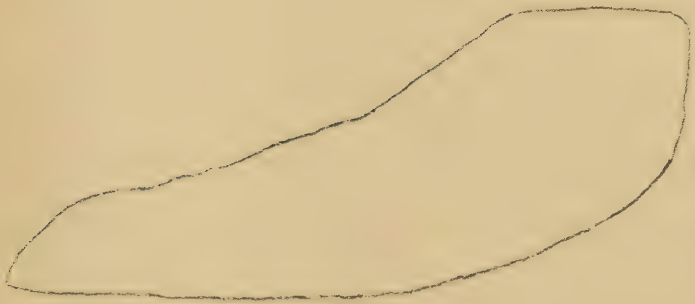
Time	CARDS		LENGTH		AREA	
	L	R	L	R	L	R
1.22	1	1	354	3.52	2.44	2.77
1.32	2	2	3.58	3.52	2.16	2.36
1.42	3	3	3.53	3.53	225	2.51
1.52	4	4	3.56	3.53	2.93	3.16
Sum			1416	1410	978	1080
Mean			3.54	3525	2445	2.70

Test # 4

Sample Cards



Right



Left

Calibration Gauge
85+38

april-22-1901

Pressure Actual	Up Reading	Down Reading	Mean
0	6.3	6.3	6.30
5	11.5	13.2	12.35
10	17.7	17.8	17.75
15	22.1	22.5	22.30
20	26.7	27.1	26.90
25	31.6	32.0	31.90
30	36.6	36.8	36.70
35	41.0	41.3	41.15
40	46.4	46.5	46.45
45	51.5	51.7	51.60
50	56.5	56.8	56.65
55	61.6	61.6	61.60
60	66.8	66.9	66.85
65	71.8	71.7	71.75
70	75.5	76.0	75.75
75	80.3	80.5	80.40
80	85.2	85.4	85.30
85	90.2	90.2	90.20
90	95.0	94.9	94.95

Calibration of Gauge (cont)

Pressure Actual	Up Reading	Down Reading	Mean
95	100	100.1	100.05
100	105.1	105.4	105.25
105	110.6	110.8	110.70
110	115.2	115.5	115.35

Calibration Indicator Springs

Spring 7051 april-20-1901

Gauge Pressure	Pressure Corrected	Ord. Descend Test 1	Ord. Descend Test 2	Mean	Ord. Ascend Test 1	Ord. Ascend Test 2	Mean	Scale Spring Descend	Scale Spring Ascend
20	12.1	.26	.27	.265	.25	.25	.25	49.3	50.5
30	23.2	.49	.49	.49	.47	.47	.47	51.0	51.0
40	33.4	.69	.69	.69	.67	.67	.67	48.7	50.
50	43.4	.89	.90	.895	.87	.87	.87	48.3	48.3
60	53.3	1.10	1.10	1.10	1.08	1.07	1.075	48.3	47.2
70	63.2	1.31	1.30	1.305	1.30	1.27	1.285	45.8	48
80	73.5	1.53	1.53	1.53	1.50	1.50	1.50		
Sum								2914	2950
Mean								48.57	49.17
Mean,								48.87	
				Spring 7052					
20	12.1	.24	.24	.24	.24	.24	.24	50.5	51.6
30	23.2	.46	.45	.455	.46	.46	.46	46.4	47.5
40	33.4	.67	.67	.67	.68	.69	.685	48.8	47.6
50	43.4	.89	.87	.88	.89	.89	.89	48.3	52.1
60	53.3	1.07	1.07	1.07	1.09	1.10	1.095	52.1	49.6
70	63.2	1.28	1.26	1.27	1.27	1.30	1285	49.1	48.0
80	73.5	.49	.48	1.485	1.49	1.50	149.5		
Sum								2952	2964
Mean								49.2	49.4
Mean,								49.3	
Mean of Both Spring								49.085	

Test to find [illegible] [illegible] for [illegible] [illegible] in [illegible]

May-13-1901

Time	[illegible]	T_1	T_2
3.09	[illegible]	312	[illegible]
3.14	98	315	224
3.19	[illegible]	313	23[illegible]
3.24	98.1	315	230
3.29	[illegible]	31[illegible]	234
3.34	98	316	23[illegible]
3.39	98	316	[illegible]
Sum	[illegible]	[illegible]	[illegible]
Mean	98.6	31[illegible]7	230

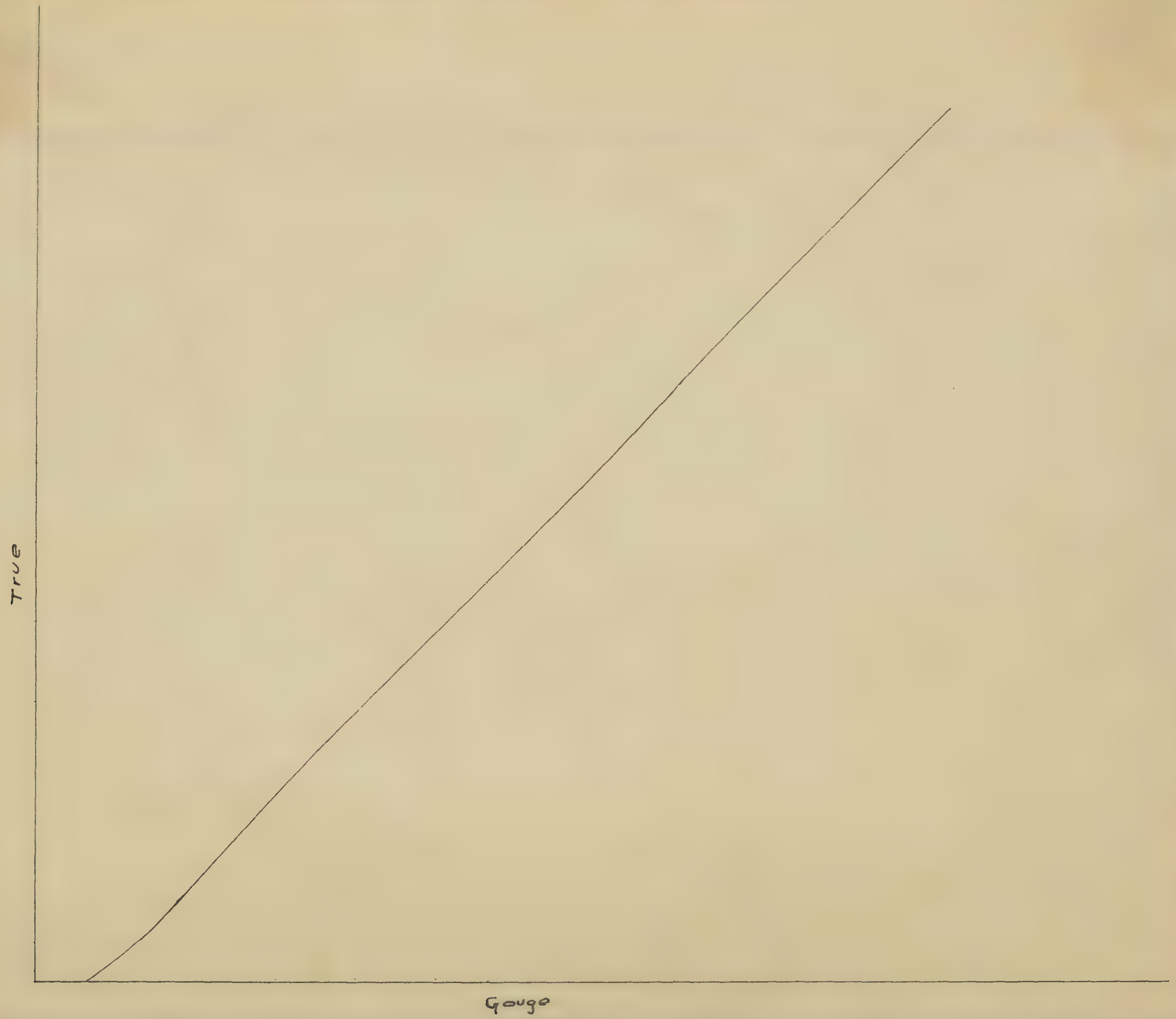
4-27-1901	Calibration		4 m. #26.
Reading Balance	Ammeter Reading	Value of Balance Reading	Error
23.1	3 0	2.89	.11
25.1	3.22	3.14	.08
28.4	3.69	3.55	.14
30.6	3.95	3.83	.12
32.5	4 20	4.06	.14
37.5	480	4.69	.11

Resistance Determination of Series Field + Armature
$R = \frac{P_R}{C_c}$

5-4-1901

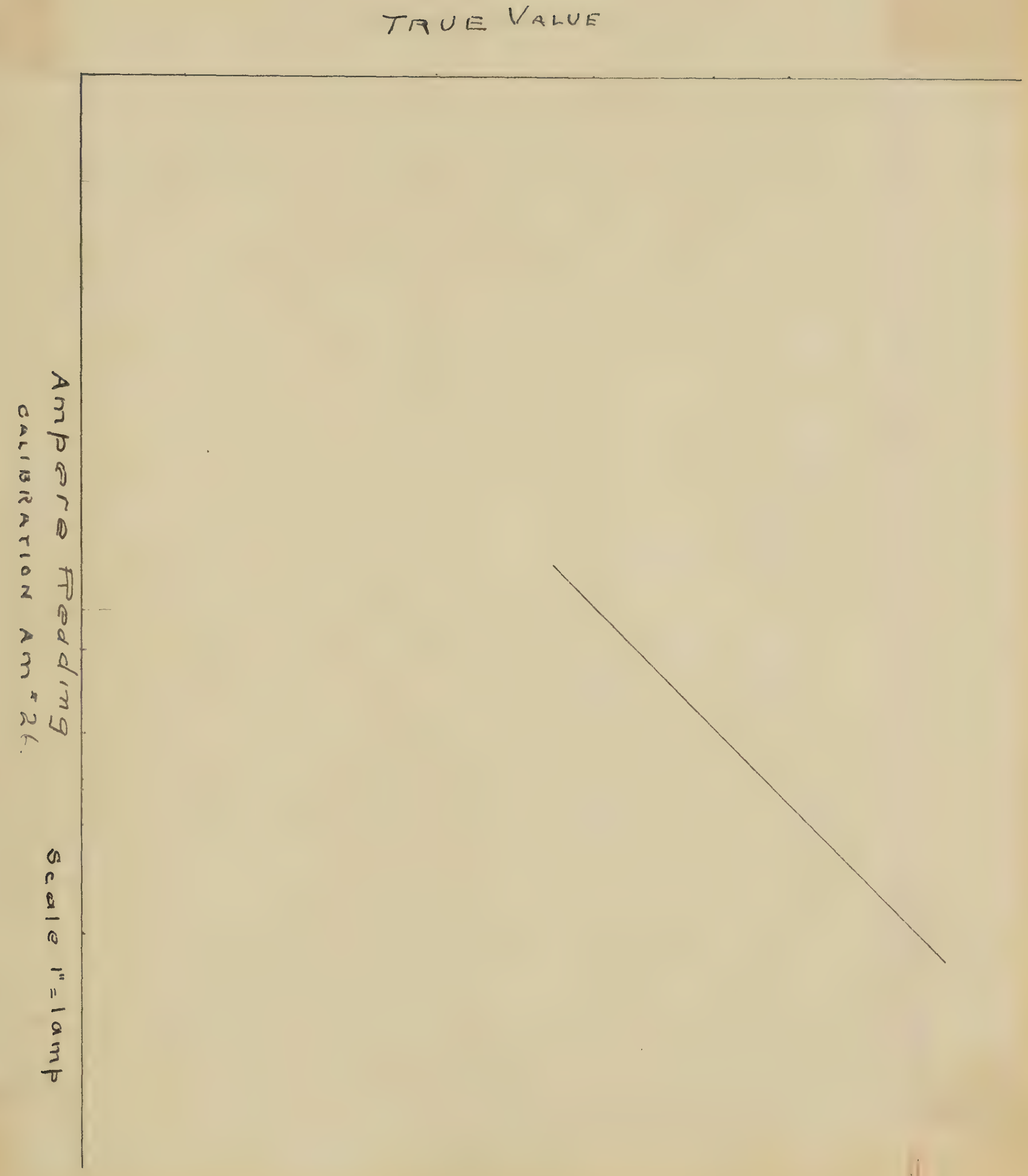
Time	Prop Pot	Corrected value in volts	Current	Corrected Current	R
11.15	8.5	.17	12.5	8.86	.0183
	10.4	.208	15.2	11.20	.0185
	11.5	.2301	17	12.22	.0189
Sum					.0557
Mean					.0186
		Armature Resistance			
	104.5	1.323	17	12.2	.1144
	86.5	1.094	13.5	9.43	.1160
	81.5	1.031	13.	9.17	.1124
Sum					3428
Mean					.1143

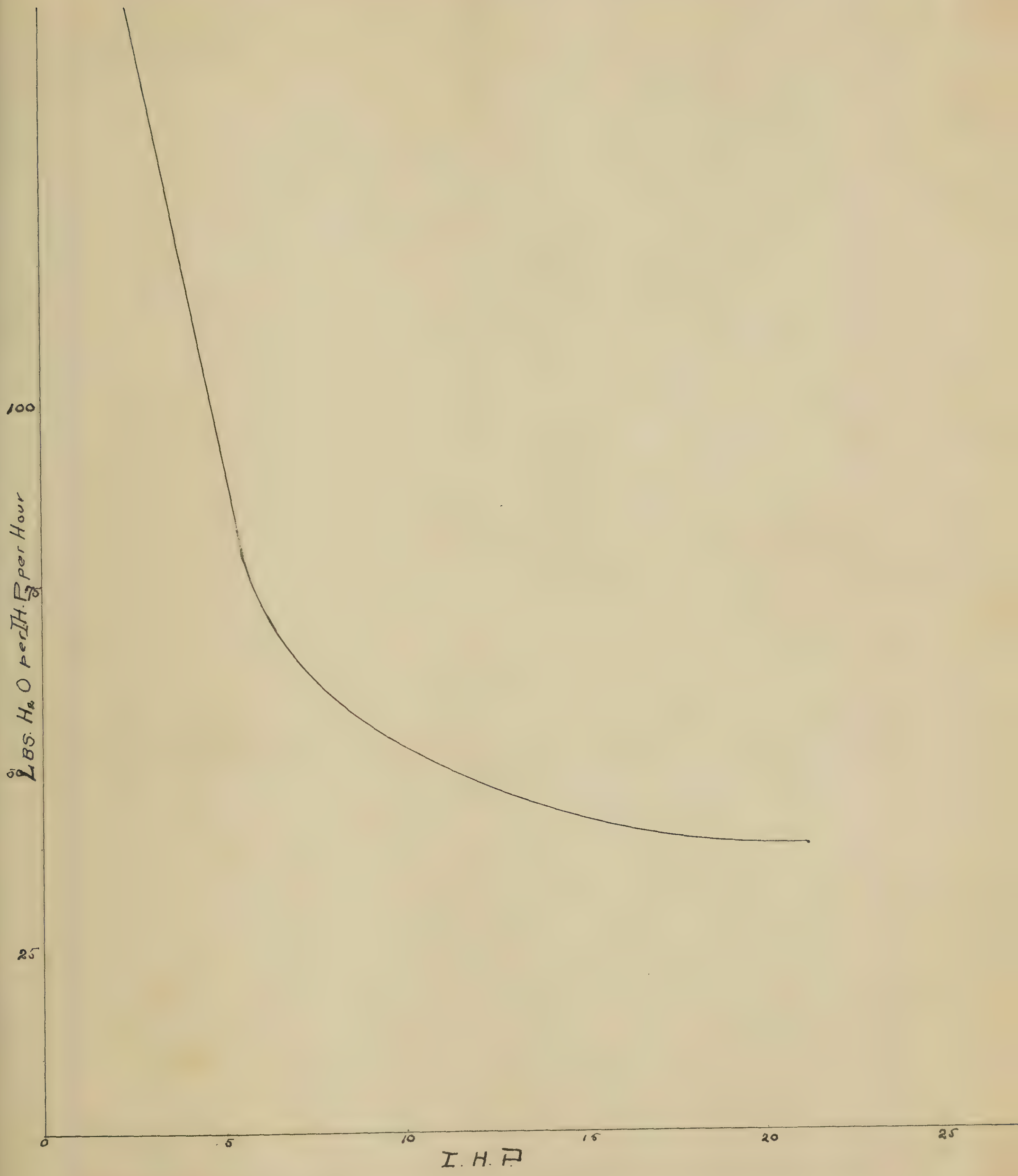
CURVES

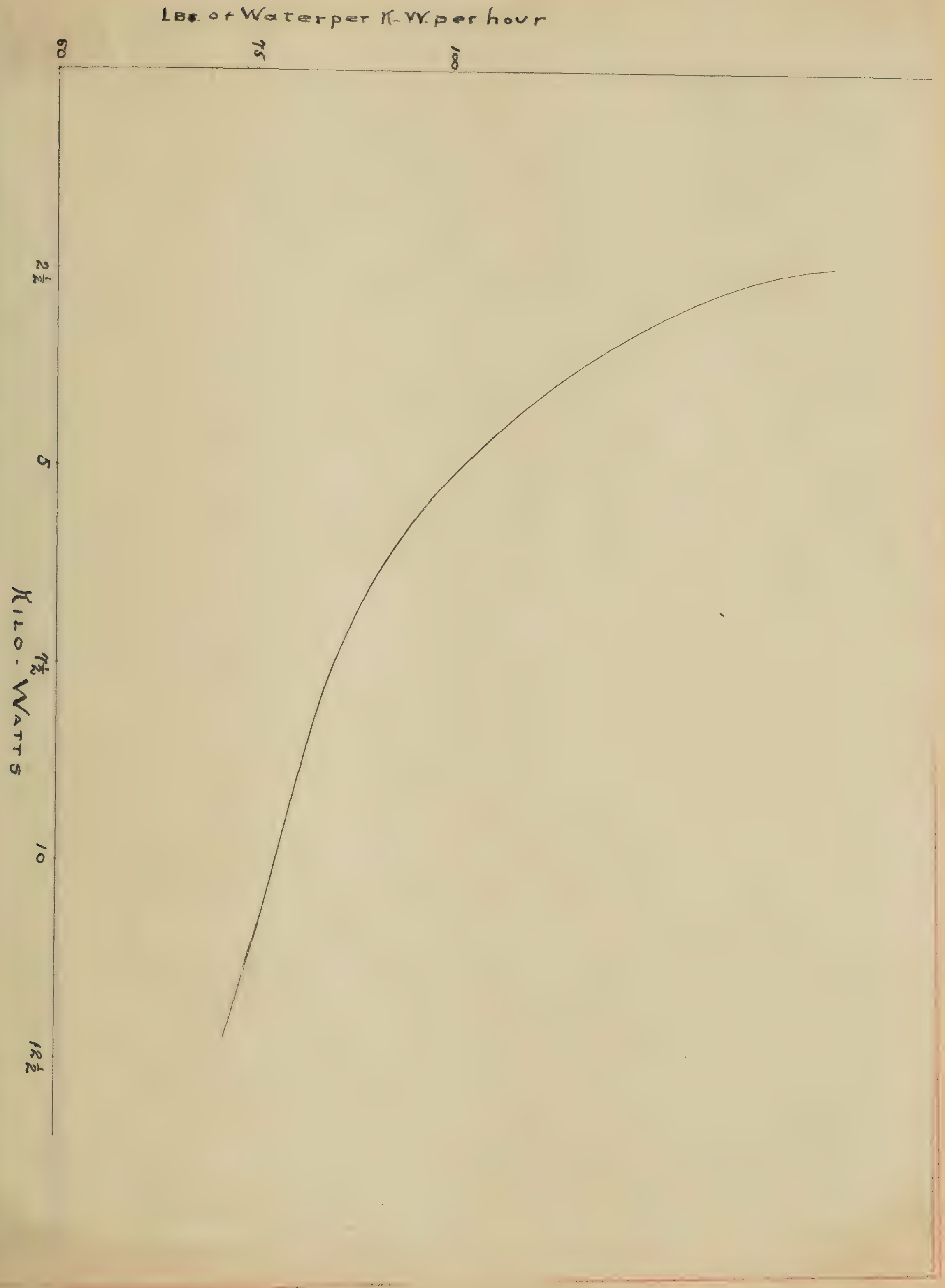


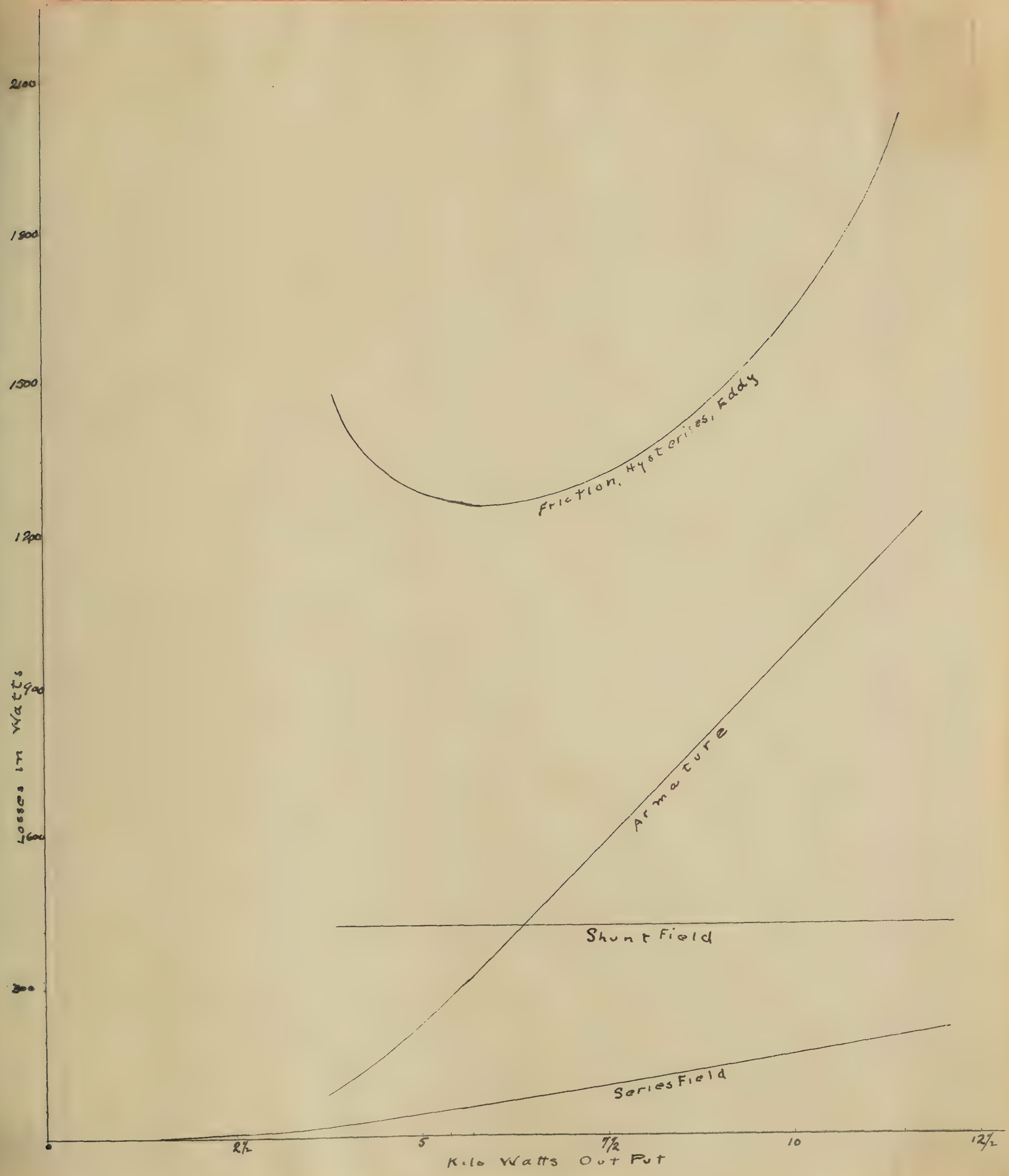
Scale $\frac{1}{20}''$ = 1 lb

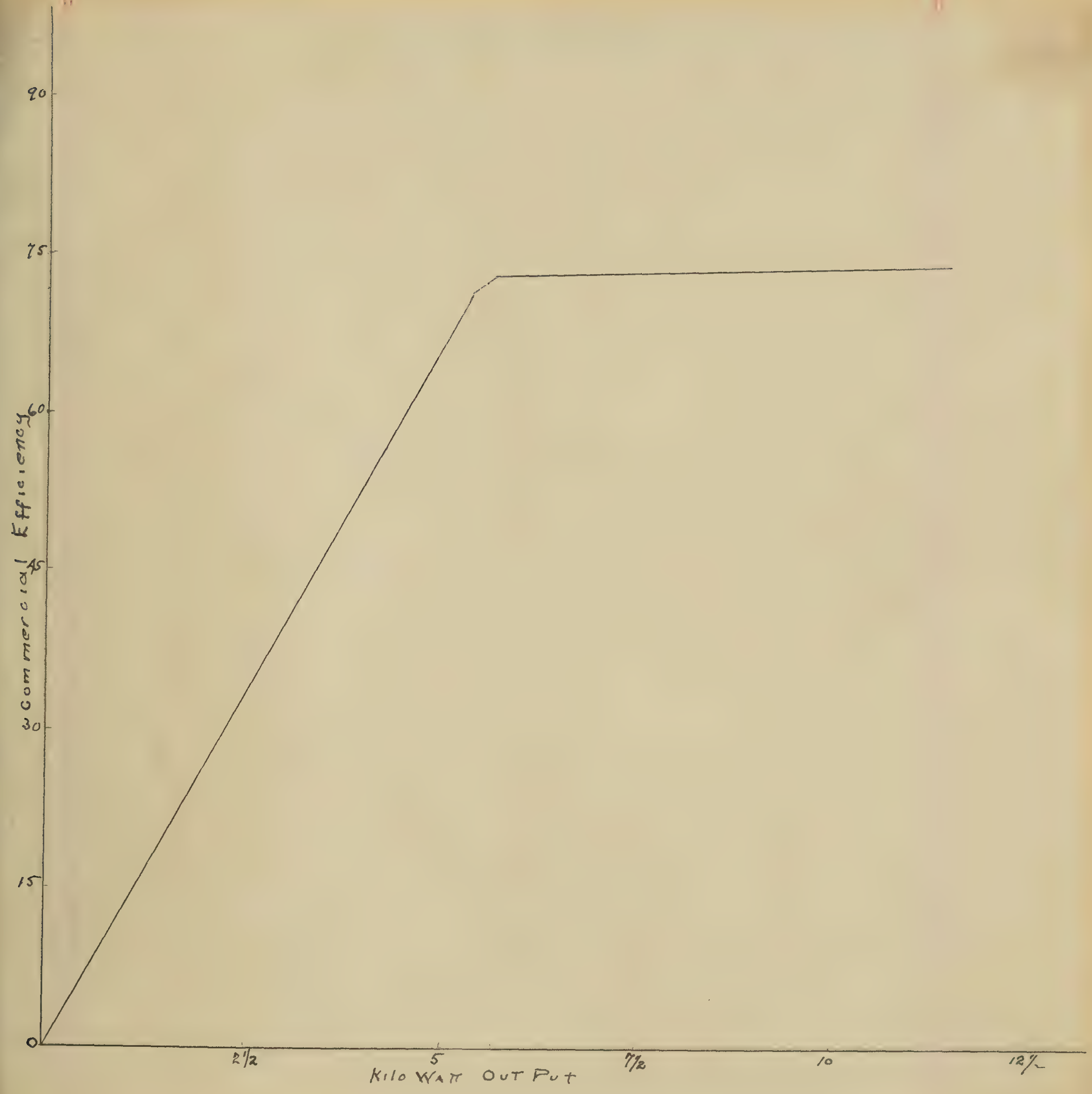
calibration
Gauge # 189438


TRUE VALUE
Ampere Reading
CALIBRATION Am * 26.
Scale 1" = 1 amp


Lbs. H_2O per I.H.P. per Hour
100
75
50
25
0
5
10
15
20
25
I.H.P.


Lbs. of Water per K-W. per hour
60
75
100
Kilo-Watts
2½
5
7½
10
12½


2100
1800
1500
1200
900
600
300
Losses in Watts
Friction, Hysterises, Eddy
Armature
Shunt Field
Series Field
2½
5
7½
10
12½
Kilo Watts Out Put


90
75
60
45
30
15
0
Commercial Efficiency
2½
5
7½
10
12½
Kilo Watt Out Put

Results

Results

First #,

Sum Mean ordinates = $\frac{1802}{352} + \frac{1566}{354} = \frac{3368}{353}$ Length of stroke = 7"

$N = 361.8$ Area of piston = 44.1784 sq"

Scale of spring 49.085

$K = \frac{7 \times 44.1784}{12 \times 33000} = .0007809$

$HP = \frac{PLAN}{33000} = .0007809 \times 49.085 \times .9541 \times 361.8$

$HP = 1.3231$

Weight of steam condensed per hour
= 344 lbs

Steam in moisture - Calorimeter result.

Mean T_2 247.3

" P 100.83 corrected 115.65

Barometer 14.638
110.288

18.2° added to T_2
for radiation
= 265.50

$$x_1 = \frac{q_2 + r_2 + .48(T_{sup} - T_{sat}) - q_1}{r_1}$$

$$= \frac{180.5 + 961 + .48(265.55 - 211.76) - 305.3}{878.5}$$

$x_1 = .987$

% of moisture 1.24 %

Results Calc. cont

Water actually condensed in engine -

344 × [illegible] = 340.4

Steam Consumption per I.H.P. per hour

$$= \frac{340.4}{1.3231} = 257.03 \text{ lbs}$$

Steam Consumption per elec. watt hour =

Test #2.

Mean ordinate right .38677

" " left .33685

Sum .72362

IHP = .0007809 × 49.085 × .72362 × 373.6

= 10.363

Mean amperes = 56.253 Corrected = 52.553

Mean volts = 108.25 " = 108.25

Mean Rev. = 373.6

$$\text{Efficiency commercial} = \frac{V \times A \times \frac{1}{746}}{10.363} =$$

$$\frac{52.553 \times 108.25}{746 \times 10.363} = 73.585\ \%$$

Weight of steam condensed per hour 55+ lbs

Percentage moisture in steam.

Mean T_2 = 244.9 + 18.2 = 263.1

" P = 100.41 Corrected = 94.38

$$\begin{array}{r} 94.38 \\ \underline{14.72} \\ 109.10 \end{array}$$

$$x = \frac{180.8 + 965.83 + .48(2631 - 212.06) - 304.6}{879.2}$$

x = .9856 % moisture = 1.44 %

Set # 2 Contd.

Steam condensed in engine 554 × .9856

= 546.01

Steam consumption per IHP per hour = 52.69 lbs

" " " KW " " = 95.97 lbs

Losses

Armature = $C^2 R$ = $52.553^2 \times .1143$ = 315.7 watts

Shunt = $E C$ = 108.25×3.84 = 415.7

Series = $C^2 R$ = $52.553^2 \times .0186$ = 51.37 watts

Total loss 782.77 wts

IHP = 10.363×746 = 7731 watts

Watts out put = 5689

Friction and other losses = 7731 − 6471.77 = 1259.23 watts.

Test # 3

Mean ordinate right end 35.14

" " left

Sum .7028

I H P = .0007809 × 49.085 × .7028 × 371 = 9.997

Mean amperes 51.54 Corrected 48.37

Mean volts 110.69 " 110.69

Mean Rev 371.

$$\text{Commercial eff} = \frac{V \times A}{746 \times 9.99} =$$

$$\frac{48.37 \times 110.69}{746 \times 9.997} = 71.94\ \%$$

Weight of steam condensed per hour 536 lbs

Percentage moisture in steam

Mean T_2 = 250 + 18.2 = 268.2

Mean P 102.08 Corrected 96.8

$$\begin{array}{r} 96.8 \\ \underline{14.72} \\ 111.52 \end{array}$$

$$x = \frac{180.8 + 965.7 + .48\,(268.2 - 212.06) - 306.3}{878}$$

x = .9854 % moisture = 1.46 %

Steam consumption per IHP per hour

$$= \frac{536 \times 485 +}{9.997} = 52.95 \text{ lbs}$$

Steam consumption per K.W. per hour 98.2

Test # 3 cont.

Losses

Armature = C^2R = $48.37^2 \times .43$ = [illegible] watts

Shunt = EC = [illegible] × 3.9[illegible] = [illegible]

Series = C^2R = $48.37^2 \times$ [illegible] = 13.52 watts

Total loss [illegible] 8.92

Effic = [illegible]

Commercial [illegible] = [illegible] 357

[illegible] = 7488 − 6135.92

= 1352.[illegible] watts

Test # 7.

Mean ordinate right = $\frac{2.70}{3.525}$ = .7659

" " left = $\frac{2.445}{3.5}$ = .6907

Sum 1.4566

IHP = .0007809 × 49.085 × 1.4566 × 363.7 = 20.357

Mean amperes 104.69 Corrected 102.23

" Volts 111.875 " 111.875

Mean rev 363.7

Commercial efficiency = $\frac{\frac{EA}{746}}{20.357}$ =

$$\frac{102.23 \times 111.875}{746 \times 20.357} = .7532$$

Weight of steam condensed for the run 815.25 lb

Percentage moisture in steam

Mean t_2 = 255.6 + 18.2 = 273.8

" P = 95.13 Corr. = 89.4
14.63
104.03

$$x = \frac{180.5 + 966.1 + .48(273.8 - 211.76) - 300.9}{881.8}$$

x = .9928 % moisture .72 %

Steam used in engine .9928 × 815.25 = 809.41

Set # 4 Cont

Steam Consumption per IHP per hour = 39.86 lb

" " " K W " " = 70.77 lb

Losses

Armature = C^2R = $102.23^2 \times .1143$ = 1194.7 watts

Shunt = Ec = .575 × 4.012 = 449.2 watts

Series = C^2R = $102.23^2 \times .0186$ = 194.4 watts

Total Loss 1738.5 watts

I.H.P. = 20.[illegible] × 746 = 15183 watts

Watts out put = 11437 watts

Friction and Windage losses =

11437 − 13175 = 2008 watts

Radiation Water Calorimeter

Furnace = 7.86 corrected 7.77

T_1 " 314.7

T_2 " 230 Barometer 29.318

7.77
1.003
8.773

calibration corresponding 8.773 = 332.9

332.9
314.7
18.2°

Therefore we used 18.2° as amount of radiation through all the test and added 18.2° to Room temperature

Thus - - 230 + 18.2 = 248.2

$$x = \frac{180.5 + 900 + 48(248.2 - 217.6) - 3034}{850}$$

x = .978

3 1198 03073 2932
N/1198/03073/2932X

3 1198 03073 2932
N/1198/03073/2932X

GE